**MUSCLE & NERVE TISSUE**

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HIR Chapter 2 & 8

**MUSCLE TISSUE**

Muscle tissue is classified into three categories: smooth, skeletal, and cardiac. There are two other ways of categorizing muscles:

1) Structurally, whether cross striations are present or not and

2) Physiologically, whether the muscle is under voluntary or involuntary control.

How these three classifications relate to each other is illustrated in the table below.

**Striated Non-striated**

**Involuntary** Cardiac Smooth

**Voluntary** Skeletal \_\_

The embryologic origin of muscle tissue is similar to that of connective tissue in that most originate from the mesoderm. The only place where it comes from another germ cell layer (ectoderm) is in the head region. Muscles of the trunk and extremities come from the myotomes which were part of the somites of that area.

Muscle cells are surrounded and supported by connective tissue that also contains the muscle's blood and nerve supply. Each individual skeletal muscle fiber (cell) is bounded by a thin connective tissue layer, the endomysium. Numerous muscle fibers grouped together form what is termed a muscle fascicle which is bounded by an areolar connective tissue septum, the perimysium. Many fasciculi grouped together form the muscle itself which is enveloped by a connective tissue sheath, the epimysium. It is important to realize that these connective tissue layers or coverings are continuous with each other. Furthermore, the epimysium is the same as the deep fascia observed in the gross lab, which envelopes and defines the individual "named" muscles.

The major function of muscles is to contract. When they contract, they cause the body to move (skeletal muscle), the blood to circulate (cardiac muscle), or the ingested food to move through the gastrointestinal tract (smooth muscle). Skeletal muscle is also important in the maintenance of what is called body postural tone. When a muscle contracts, it shortens in length, and potentially generates tension. A muscle must relax to lengthen, and so cannot produce tension when in the lengthening phase of muscle contraction.

Since the three types of muscle do such different jobs, they have quite different characteristics. The three muscle types are like different kinds of runners: 1) the smooth muscle is like the marathon runner, it is a slow contractor but has a very long duration of contraction; 2) the cardiac muscle is like the miler; it has a medium speed, a moderate duration of contraction, and endurance. This allows them to run in several track events, or in the case of the heart muscle, provide the repeated contractions necessary throughout life. 3) The skeletal muscle is like a sprinter, it is a very fast contractor for a very short period of time. It tires easily, especially white skeletal muscle.

Skeletal and cardiac muscle fibers appear to be more complicated in contractile organization than smooth muscle. However, much less is known about the mechanism of contraction in smooth muscle so that such a statement may not, in reality, be totally valid. Skeletal muscle fibers are cylindrical in shape and have many peripherally located nuclei. With extensive use, these fibers grow (hypertrophy) by increasing their diameter and intracellular content of the contractile proteins.

**Skeletal muscle fibers** can also be classified according to their diameter and amount of myoglobin in the sarcoplasm. These red, white and intermediate fiber types also differ in contractile properties. Red fibers are characterized by their small diameter and large amount of red myoglobin in the sarcoplasm (darker staining). These fibers also have a greater number of mitochondria present, and their source of ATP is linked to oxidative metabolism. These slow twitch (tonic), Type I fibers are capable of carrying out sustained activity over a prolonged period. They are usually found in large numbers in postural muscles.

White fibers are characterized by a large diameter with pale sarcoplasm due to small amounts of myoglobin (lighter staining). They have fewer mitochondria than the red muscle. These fast twitch (phasic), Type IIB muscle fibers are characterized by short bursts of activity and are generally found in muscles used in fine motor activity (extraocular and some hand muscles). Their major source of ATP production is via glycolysis, and the end product under anaerobic conditions is lactic acid. The Type IIA muscle fibers have characteristics intermediate between the red and white muscle fibers. While their rates of contraction are fast, they share both glycolytic and oxidative metabolic pathways for ATP regeneration. In reality, most human skeletal muscles are a complex and variable mixture of all three types, with relative portions related to the physiological role of the muscle. This gives skeletal muscle a wide range of engineering properties.

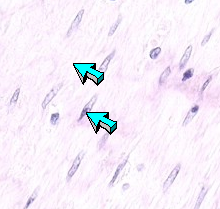
Within the sarcoplasm (cytoplasm of muscle cells) are found myofibrils which comprise the contractile elements of the cell. These myofibrils, in skeletal and cardiac muscle, are highly organized, and are found to have a system of cross striations observed in the light and electron microscope as a series of light and dark bands. The bands are named according to their effect on polarized light. Those appearing light with *polarized light* are doubly refractive and are termed anisotropic or A bands. Those appearing dark with *polarized light* are relatively non-refringent and are termed isotropic or I bands. Keep in mind that this is a very old form of striation classification. It is important to note that sinceyour microscopes use non-polarized light*,* ***you will observe the A bands as dark lines, and the I bands as light lines****,* an effect opposite to that seen with polarized light.

Higher magnification of the myofibrils reveals that they are composed of smaller filaments, the myofilaments held in registration by the Z-line. The interaction of the two types of myofilaments, the actin and myosin, produce the banding or striation pattern and the contraction mechanism of the cell. The A-band, the wide dark staining band of the sarcomere consists primarily of myosin filaments. Sometimes you can visualize a light line, the H-band, in the center of the A band. This H band is a region devoid of the interdigitating actin. The I band, the light staining bands containing actin, have a dark line, Z line, down the center of the I bands. The Z line serves as an attachment point for the actin filaments. The area between two Z lines is termed the sarcomere. Further details of the myofilaments are observed only with the electron microscope and elucidated further by biochemical techniques.

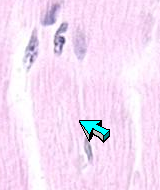
**BE CERTAIN TO VIEW THE DEMONSTRATION EM'S, WHICH ADDRESS**

**SEVERAL OF THESE KEY POINTS.**

[**[MCO 0031]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0031&type=ax&section=muscleandnerve)Muscle Composite [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0031&type=jv&section=muscleandnerve) HIR-*frames 21,45,70*

(Smooth Muscle cells & their nuclei) (cork-screw nuclei = contracted , spindle = relaxed)

(Cardical Muscle cells and nuclei) (Cardic Muscle cell Branching)

(Skeletal muscle and multiple, peripheral Nuclei) (Cross striations)

Distinguish the histological differences between the three types of muscle. Make sure to study the demonstration electron micrographs to determine the ultrastructural differences between skeletal, cardiac and smooth muscle.

**Light Microscopic Level**

**Cardiac Skeletal Smooth**

 Striated, Striated Non-striated

Med. staining density Med. staining density Pale staining

Bundles of fasciculi Parallel bundles of Bundles of cells

with different fasciculi - same usually parallel

directions - inter- direction

mixed

Single or binucleated Multinucleated Single nucleus

Central nucleus Peripheral nuclei Central nucleus

Blimp-shaped nucleus Oval discs nuclei Cigar-shaped nucleus

Branched cells Unbranched cells Tapered cells

Intercalated discs None None

Z lines Z lines Dense bodies

T-tubules/diads Triads None

No regeneration Satellite Cells Direct regeneration

**Ultrastructural Level**

Branched myofibrils Straight myofibrils Myofilaments only

Sarcomeres Sarcomeres None

A & I Bands A & I Bands None - dense bodies

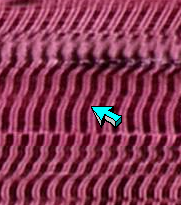
Intercalated discs None None - Gap junctions

T-tubule at Z line T-tubule at A-I junc. None-pinocytotic

vesicles

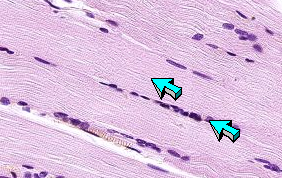
**SKELETAL MUSCLE**

[**[LH 0046]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf1_LH0046&type=ax&section=muscleandnerve)Skeletal Muscle [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf1_LH0046&type=jv&section=muscleandnerve) HIR-*frames 18-19*

* *

(cross striations of skeletal muscle) (Z-line)

[**[SL 003]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf4_SL003&type=ax&section=muscleandnerve) Skeletal Muscle [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf4_SL003&type=jv&section=muscleandnerve)

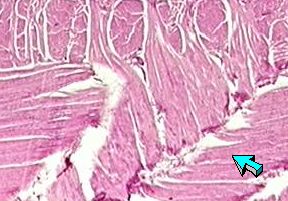
 

(Muscle Cells and peripheral nuclei) (Cross-section and nuclei) (Endomesium)

 (Red & white Muscle Fibers)

\*\*\*Which fiber stains darker depends on the stain🡪 This is stained for myoglobin so the darker ones are red fibers but if it were stained for glycogen the darker fibers would be the white fibers

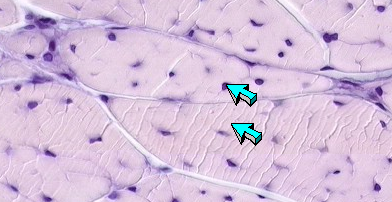
[**[UTN 079]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf5_UTN079&type=ax&section=muscleandnerve) Tongue Cornification, Cat (H&E) [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf5_UTN079&type=jv&section=muscleandnerve)

(Longitudinal and Cross sections) (Oblique orientation)

**LH 0046** contains isolated skeletal muscle fibers. It is an excellent example of the individual longitudinal muscle fibers and their striations. Identify the different bands and sarcomeres in this section. There are both longitudinal and cross sections of skeletal muscle fibers on slides **SL 003** and **UTN 079**.

[**[MCO 0009]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0009&type=ax&section=muscleandnerve) Tendon [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0009&type=jv&section=muscleandnerve)

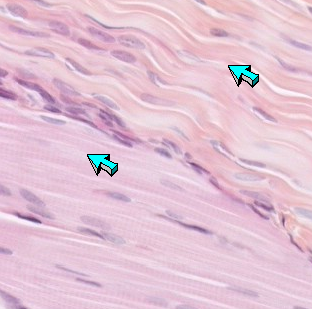
(Dense Regular CT with nonperipheral nuclei) \*\*\*looks like skeletal muscle

Be able to distinguish and identify the tendon in both longitudinal and cross sections. The tightly packed collagen bundles are wavy in longitudinal section and lack cross striations. In addition, the elongated nuclei squeezed between the bundles are characteristic. In cross section, the *stellate shaped nuclei* appear to be scattered throughout the bundles and not just located at the periphery of the bundles. Areolar connective tissue separates the larger bundles, carries capillaries and permits them to slide past each other during movement.

**[A WARNING:]**

*Be sure that you can distinguish skeletal muscle from its histological look-alike, tendon, in both cross & longitudinal sections. This can be done by observing that the nuclei in the tendon are outside the edges of the bundles of collagen fibers, and the fibers show no sign of striations. The fibroblast nuclei are stellate in shape in contrast to the rounded plate-like nuclei of the skeletal muscle. Also, tendon fibers are much smaller in diameter than skeletal muscle fibers. Finally, there are no marked striations at the LM level.*

[**[MCO 0032]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0032&type=ax&section=muscleandnerve)Muscle-Tendon Junction [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0032&type=jv&section=muscleandnerve) HIR-*frame 35*



[**[SL077]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf4_SL077&type=ax&section=muscleandnerve) Tendon [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf4_SL077&type=jv&section=muscleandnerve)



The union of muscle with tendon consists of a merging of the connective tissues of both structures. In **MCO 0032** distinguish between the tendon (paler staining, wavy appearance, and elongated nuclei located between the fibers on far right side of section) and the skeletal muscle (darker staining, larger diameter cells, cross striations and oval nuclei located at periphery of the cells). Look for areas where the ends of muscle cells run into the ends of bundles of collagen fibers. The connective tissue which surrounds the muscle at this point is formed into a "harness." Realize that this harness is formed by the fusion of the ***epi, peri- and endomysium*** around the tapered end of the muscle. The function of this harness is to transfer the tension from the individual fibers to the tendon. The red staining tissue in **SL 077** is the dense regular connective tissue of the tendon that is surrounded in the pink-staining, striated, skeletal muscle.

[**MCW 206]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf3_MCW206&type=ax&section=muscleandnerve)Motor End Organs [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf3_MCW206&type=jv&section=muscleandnerve) HIR-*frames 37, 461, 462, 491*

(Motor end Plates)

 This is a silver stained whole mount preparation showing myoneural junctions.Motor nerve fibers which supply a muscle may branch repeatedly within that muscle. A terminal branch of the axon from a motor neuron will usually end about midway along the length of that muscle cell (fiber). There it will lose its myelin sheath just prior to forming a terminal arborization. This area appears as a flattened oval or round mound termed the motor end plate. As the large myelinated axon enters the mound, the myelin sheath is lost. The area without a myelin sheath may be observed as a thin area. Look at the darkly-stained crow�s foot pattern of the terminal arborization. These bulbous terminations are where the membrane of the neuron and the sarcolemma of the muscle are separated by the synaptic cleft.

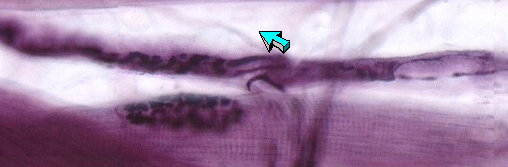
Each motor axon branches to supply several motor end plates which together comprise a motor unit. Thus each muscle fiber is innervated by a single motor end plate, but a given motor axon can innervate many muscle fibers. These nerve processes are carrying motor impulses toward the muscle fibers to initiate voluntary muscle contraction.

Demonstration Micrographs: Myoneural Junction

Please pay close attention to the two demonstrations. Observe the EM's and associated drawing which show primary and secondary structural features of the myoneural junction, also called the Motor End Plate. Know the neurotransmitter used in this location. Know what its specific action is. Know the structures where and how this signal molecule is destroyed, and reformed.

[**[MCO 0041]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0041&type=ax&section=muscleandnerve) Muscle Spindle [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0041&type=jv&section=muscleandnerve)

HIR-*frame 491*



(Spindle cells) \*\*\*Also annulospiral (can see) & flower spray nerve ending (cannot see)

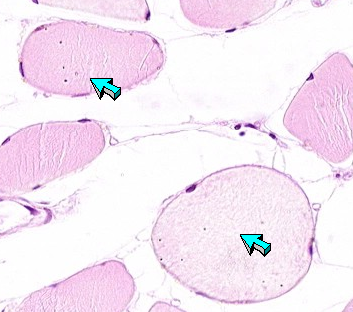
[**[UW 127]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf7_UW127&type=ax&section=muscleandnerve)Muscle Spindle [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf7_UW127&type=jv&section=muscleandnerve)

 (Muscle spindle & Nuclear chain cells)

\*\*\*Nuclear bag cells are not seen in this slide but would have lots of balled up nuclei)

These slides demonstrate the stretch receptors within skeletal muscles which act to regulate muscle tone. The first slide is silver stained to show *just the neural elements* of this long spindle shaped structure wedged in between normal skeletal muscle fibers. Contrast this to the motor end plates also present. The second slide **UW 127** has three cross sections of skeletal muscle containing the H&E stained cross section of muscle spindles. Each section contains one spindle in cross section (approximately in the center of the section) that demonstrates the *cellular elements* of a spindle. Look for the connective tissue capsule surrounding cross sections of one to five small intrafusal fibers.

[**[MCO 0030]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0030&type=ax&section=muscleandnerve)Skeletal Muscle, Myoglobin [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0030&type=jv&section=muscleandnerve)

(Red & white Muscle Fibers)

\*\*\*Which fiber stains darker depends on the stain🡪 This is stained for myoglobin so the darker ones are red fibers but if it were stained for glycogen the darker fibers would be the white fibers

In this cross section of muscle, the fibers are ***stained for their myoglobin content***, and thus according to their metabolic fiber type. *Red fibers*, with the most myoglobin content, are darkly stained. These fibers have the smallest diameter, and the least amount of stored glycogen. Large *white fibers* have a low myoglobin content and a high glycogen content (due to their capacity for anaerobic metabolism), and are pale in appearance. *Intermediate fibers* are somewhere in between in both size and staining properties, but because of the staining properties of these sections they *are somewhat difficult to identify*. The purpose of this slide is to underscore that in most human muscle, the fiber types are mixed within the muscle itself*. See demonstration*.

**CARDIAC MUSCLE**

 Cardiac muscle is the striated muscle contained in the walls of the heart. There are several distinct differences, histologically, from skeletal muscle. In skeletal muscle, the fasciculi run in the same direction while in cardiac muscle the fasciculi have different directions of orientation. Cardiac muscle cells also show branching and a specialized intercellular junction called intercalated disk. But the most characteristic distinction of cardiac muscle from skeletal muscle is that there is only one (or two) nucleus per cell or area between the intercalated disks. These nuclei are located centrally while the multiple skeletal muscle nuclei are located peripherally.

Cardiac muscle also has an abundant blood supply identified by numerous capillaries. The fine connective tissue between the muscle cells is either endomysium or perimysium.

[**[MCO 0034]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0034&type=ax&section=muscleandnerve)Purkinje Fibers, Human Heart [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0034&type=jv&section=muscleandnerve) HIR-*frames 45-48*

These slides contain sections of cardiac muscle. Study the cardiac muscle of these slides and familiarize yourself with their characteristics. It is stained with a Mallory or Masson type of stain which accentuates connective tissue elements (green). Intercalated discs are present but difficult to find on these slides. Try to locate them in areas where the muscle is longitudinal in orientation.

[**[UW 139]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf7_UW139&type=ax&section=muscleandnerve)Cardiac Muscle, Human[**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf7_UW139&type=jv&section=muscleandnerve) HIR-*frames 46, 58*

 (Branching of cardiac muscle and intercalated dick)

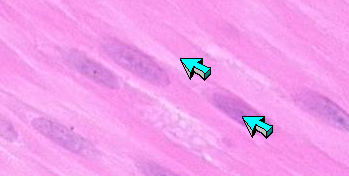
 \*\*\*can only see transverse region of the intercalated disk

This slide demonstrates the characteristics of cardiac muscle and accentuates intercalated disks. What are the key diagnostic characteristics that are different between cardiac and skeletal muscle? [See previous table] Know the difference in function between the transverse region versus the lateral region of the intercalated disk.

**SMOOTH MUSCLE**

 Smooth muscle is found in the walls of many tubular organs of the body including those found in the circulatory, digestive, urinary, and reproductive systems, as well as in other areas of the body. Changes in smooth muscle contraction are important in the regulation of blood pressure. The smooth muscle layers may be circularly arranged, as in blood vessels, or circularly and longitudinally arranged, as in the digestive and urinary system. These cells may be short (e.g., small arterioles) or long (e.g., uterus) but all are fusiform or spindle shaped and have one centrally placed nucleus. Because of the fusiform shape, cross sectional areas show fibers of different diameters, some with nuclei, others without. The nucleus has a distinctive "cork screw" twisted appearance when seen in longitudinal section of contacted muscle.

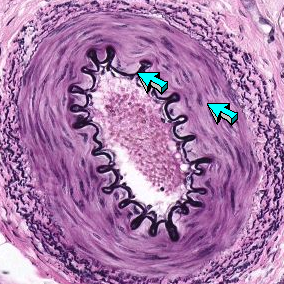
[**[LH 0130]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf1_LH0130&type=ax&section=muscleandnerve) Jejunum [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf1_LH0130&type=jv&section=muscleandnerve) HIR-*frame 970*



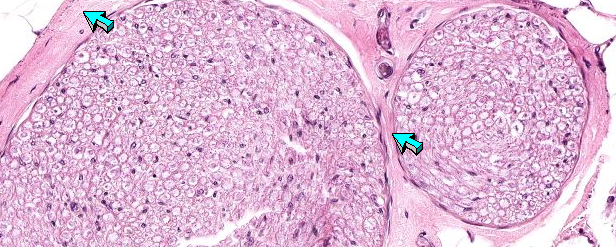
(Spindle shaped cells and elongated nuclei)

Observe the smooth muscle of the tunica muscularis (muscularis externa). The jejunum shows both a circular and longitudinal layer of smooth muscle. Be able to recognize smooth muscle in both longitudinal and cross section. Note the fine chromatin of the oval nuclei and the homogeneous sarcoplasm which is eosinophilic. Realize, as with skeletal muscle, there is an intimate relationship between the smooth muscle fibers and the investing connective tissue elements (epi-, peri-, and endomysium).

[**[MCO 0658]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0658&type=ax&section=epithelium) Artery, Vein & Nerve, Elastic Tissue **[Java](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0658&type=jv&section=epithelium)**

(Internal elastic lamena & smooth muscle) (Nuclei of contracted cell & non contracted)



(Epineurium and perineurium or nerve fiber and nerve bundles)

[**[MCO 057]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0057&type=ax&section=muscleandnerve)Artery, Vein, Nerve, Cross Section [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0057&type=jv&section=muscleandnerve)

 (Myeline sheath = foamy white, Axon = darker center)

These slides are old friends from the Epithelial Laboratory. Now look at the smooth muscle layer between the two elastic tissue layers, in the smaller muscular artery (round lumen). The muscle cells in the larger vein, (irregular shaped lumen) are not as numerous. One should be able to see some **spectacular examples** of the twisted nuclei of smooth muscle cells.

**NEURAL TISSUE**

 The nervous tissue may be subdivided into two components: The nerve cells (neurons) and supportive cells (neuroglial cells).

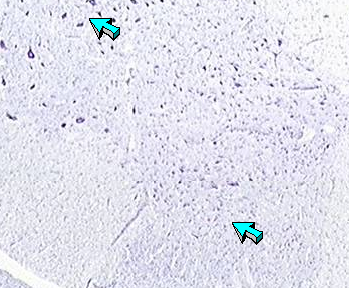
**NEURONS**

 The neuron is the fundamental functional unit of the nervous system. It is composed of a cell body or perikaryon or soma and cell processes called dendrites and axons. Neurons may be classified morphologically by the number of cell processes, as multipolar, unipolar, bipolar.

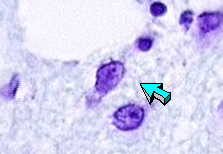
***Most of the slides which you will examine today are stained to show components of the cell body to their best advantage (Nissl Stain), but it is important that you realize that a significant portion of the neuron (it's axonal and dendritic processes) are not clearly seen in such stains.***

1) Multipolar neurons have one axon and several (2 or more) dendrites and are typically found in central nervous system structures such as the ventral gray column of the spinal cord (ventral horn), cerebral cortex (pyramidal cells), and cerebellar cortex (Purkinje cells) as well as the sympathetic ganglia in the peripheral nervous system. Observe the following slides which contain multipolar neurons.

[**[MCO 0035]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0035&type=ax&section=muscleandnerve) Nissl bodies, neurons [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0057&type=jv&section=muscleandnerve) HIR-*frames 431, 434*

(ventral and dorsal horn) (Larger spinal motor multipolar neuron & nissl body)



(Smaller sensory neurons in dorsal horn)

Use low magnification to get oriented to this transverse section through the lumbar region of the spinal cord. The main oval mass contains a large, slightly darker staining central butterfly (or "H"-shaped) region surrounded by lighter staining material (white matter) at the periphery. The ventral side of the cord is at the top of the section and dorsal side is at the bottom of the section.

A small cavity, the central canal of the spinal cord, is located in the center between the two wings of the butterfly. Cerebrospinal fluid flows through this canal, which is lined by ependymal cells. These are darkly staining simple cuboidal to low columnar cells. They may appear somewhat irregular due to tissue distortion in your specimens. Ependymal cells serve as the "epithelial-like" lining of all of the ventricles in the brain and as such they possess surface specializations including microvilli and cilia. They are distinguished from true epithelial cells by the fact that they do not rest on a basement membrane and are classified as glia or supporting cells.

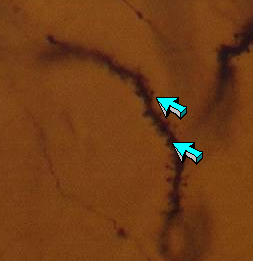
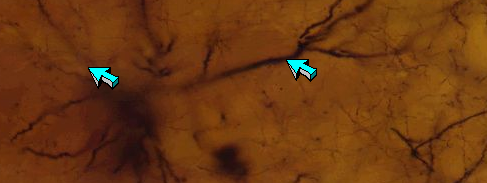
The butterfly-shaped region makes up the gray matter of the spinal cord and is darker staining due to the large number of neuronal cell bodies (perikaryon, or somas) present. The smaller part of the wings, which extend dorsally to the edge of the spinal cord are the posterior (dorsal) horns (bottom of section). The anterior or (ventral) horns are larger, more rounded, but do not extend to the edge of the cord. The dorsal roots and ventral roots of spinal nerves are smaller bodies of nerve tracts outside the spinal cord near the respective horns.

Examine this slide for multipolar neurons, which are found in the anterior horn. These are the large, darker staining polygonal cells. The perimeter of these cells is somewhat irregular due to the emergence of multiple dendrites from the soma. At higher magnification, the cytoplasm is violet or darker staining due to the presence of many small granules. The granules are the "Nissl bodies". These are numerous aggregates of rough ER that indicate the high degree of protein synthesis that is occurring in these cells. Each of these neurons contains a large, pale staining, centrally located nucleus with a prominent dark nucleolus.

These neurons have many processes extending from them which cannot readily be seen in this stain. Nissl substance extends only into the most proximal portions of the dendrites and some of these may be seen in the larger neurons as blunt conical shape stumps which appear to end abruptly. The axon may be distinguished by the presence of the axon hillock, a larger, tapering, conical shaped region of the perikaryon at the base of the axon process, which does not contain any Nissl substance. Therefore, it is lighter staining than the rest of the perikaryon and dendrites which contain Nissl substance.

Observe the numerous small dark staining nuclei in both the gray and white matter of this tissue. These are the nuclei of the smaller neuroglial cells which serve a supportive function. Individual glial cell subtypes cannot be distinguished in this stain.

[**[MCO 0043]**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0043&type=ax&section=muscleandnerve) Cerebral Cortex Golgi [**Java**](https://www.utdl.edu/WebSlides/launch.php?name=_BLIvf2_MCO0043&type=jv&section=muscleandnerve) HIR- *frame 430*

(dentrites & axon) (Dentrite & dendritic spines) (Cell Body & pieces of other axons)

This slide is a section taken through the cerebral cortex and stained with a reduced silver method called the Golgi technique (after the 19th century Italian neuroanatomist Emelio Golgi). The Golgi technique stains only a small proportion of the neurons in the tissue (10-20%), but those that do stain are stained quite completely, including their dendritic and axonal processes. This stain gives the most accurate picture of the organization and complexity of these neuronal processes. Ignore the large artifactual black splotches of deposited silver. Try to scan the edges of the tissue at low power for a region with few, well-stained neurons.

Look at the region near the surface of the cortex for areas where several cells have accumulated the stain. The globular cell bodies are easily seen, while their intracellular contents are obscured by the density of this stain. *Note at higher power the fine detail of the neuronal processes*. Note also the variety of shapes and sizes evident in these cortical neurons. Specific types of cortical cells located in different regions of the cortex form the basis for cortical lamination which you will learn more about in the Neuroscience course.

Observe the vertically oriented dendritic trees of many of the larger pyramidal cells. These dendrites form the receptive surface of these neurons and are contacted at synaptic junctions by thousands of axon boutons from other neurons which do not stain with this method. A specialized region of synaptic contact on these dendrites, called dendritic spines, can often be seen as tiny spine-like protrusion issuing from the surface of the dendritic processes. Follow the apical dendrite of one of these neurons towards the surface of the cortex and observe these features. Note also the different arrangement of the dendritic branches around the soma of these neurons. Some cells show a rather radial orientation of their dendrites while others show a more polar arrangement. The shape of the dendritic tree forms the basis for a complex classification scheme of cortical neurons that you will learn more about in Neuroscience. The axons of these cells will often be difficult to pick out among the dense meshwork of the dendritic tree. They are generally oriented away from the cortical surface and are much *thinner* than the dendrites and devoid of dendritic spines. Try to visualize one of these processes in your specimen.

2) Unipolar or pseudounipolar (T-cells) neurons have only one cell process, a T-shaped process which bifurcates with one branch directed peripherally which functions as an axon, the other directed centrally which functions as a dendrite. Both processes are commonly myelinated and are frequently referred to as the central and peripheral axon. The peripheral axon extends to the periphery, while the central axon projects into the central nervous system. These unipolar neurons transmit impulses which are stimulated by receptors for pain, temperature, touch, etc. and are notably found in the dorsal root ganglia of spinal nerves (will look at below) and semilunar ganglia of the trigeminal nerve, the sensory ganglia of cranial nerves VII, IX, and X as well as the mesencephalic nucleus of V. The mesencephalic nucleus is the only example of unipolar neurons with cell bodies situated within the central portion of the nervous system.

3) Bipolar neurons have one axon and one dendrite extending from opposite ends of the perikaryon. These cells are most notably found in the retina of the eye (bipolar cells, which synapse with the rods and cones), olfactory epithelium of the nose, and the spiral ganglia of the inner ear. You will identify these cells when you study the eye and ear.

**NEUROGLIAL CELLS**

Neuroglial (glial) cells are specialized non-neuronal cells which probably have a supportive function, although their specific functions are still being explored. This support may be in the form of physical as well as nutritional support and those glial elements found along the neuronal processes may be involved in the propagation of action potentials along adjacent nerve fibers. The latter involves the formation of a myelin sheath around the neuronal processes and is comprised of oligodendrocytes (CNS only) or Schwann cells (PNS only). At the light microscopic level it is not possible to distinguish between the different types of glial cells with H&E and silver stains because only the nuclei are visible. The nuclei of these cells can be seen scattered between the large multipolar neurons in this slide.

**PERIPHERAL NERVE**

Peripheral nerves are composed of nerve cell processes (axons and dendrites) which are held together in bundles or fascicles by connective tissue. The layers of connective tissue are named similar to that used in muscle. The connective tissue enveloping a single axon or dendrite is termed the endoneurium, that enclosing a fascicle is termed the perineurium, while the connective tissue surrounding the entire nerve is the epineurium.

Located within the endoneurium and entirely surrounding the axon (in a myelinated nerve) or partially surrounding the axon (in a nonmyelinated nerve) are Schwann cells. These Schwann cells form the myelin sheath. The point between two Schwann cells (as one is observing a longitudinal section of a peripheral nerve) is termed the node of Ranvier, while the area between nodes is the internode. A myelin sheath between two nodes of Ranvier represents the myelin contribution of a single Schwann cell (internodal segment). The axon is unmyelinated at the node itself and is covered only by the basement membrane of the Schwann cells.

This slide contains both longitudinal and cross sections of myelinated peripheral nerves. The details of the axon and its myelin ensheathment are readily seen in longitudinal sections. Since the path of axons are quite tortuous, weaving in and out of the plane of the section, it will take a bit of scanning to find a reasonably long straight section of a axon for inspection. In longitudinal section at higher magnification), the individual nerve axon is a thin brownish band surrounded by a clear or foamy appearing region. The foamy region is due to the lipid being extracted out of membranes of the Schwann cells which form the myelin sheath. The remaining flocculent protein is called neurokeratin.

The neurilemma, the outermost plasmalemma of the Schwann cell, appears as a thin dark pink line at the periphery of the foamy region on each side of the axon. A node of Ranvier, where two adjacent Schwann cells abut against each other, can be recognized in longitudinal sections as a pinching in of the neurilemma to the axon. Any nuclei observed adjacent to the axons are those of Schwann cells and not those of neurons. Since this is a section through a myelinated peripheral nerve, the nerve cell bodies which give rise to these axons are most likely located distantly in the dorsal root ganglion or spinal cord.

In cross sections, the individual myelinated axons will appear round. There will be a dark dot in the center (axonal process) of a clear or foamy region (extracted lipid of the myelin sheath) and a dark line at the periphery (neurilemma). The nuclei of the Schwann cells are located outside the axons. Identify the endoneurium, perineurium, and epineurium in cross section.

This very dark stained cross section of peripheral nerve has been fixed and stained with osmium tetroxide which preserves the black myelin sheath intact. The thick black donut ring is the mylin heath wrapped around the central light-staining nerve process.

This slide contains several bundles of nerve (far left side) (as well as arteries, and veins) in cross section. Notice that in some of the cross sectional areas there are nerve fibers that have been cut tangentially or longitudinally because of their slightly wavy path within the fascicle. Use this slide to test your knowledge by identifying the various structures of a peripheral nerve.

**GANGLIA**

This autonomic ganglion contains large, multipolar neurons *evenly distributed across the entire ganglion*. The large cell bodies (15-60 μm diameter) contain an *eccentrically placed nucleus* with a prominent nucleolus. Although neuronal cell processes are difficult to visualize on this slide, try to differentiate between the axon hillock and dendrites. Some slides sets contain slides stained with a trichrome stain, which shows the connective tissue surrounding nerve fascicle in green and the neurons with a somewhat purple stain.

Surrounding the perikaryon of each neuron is a single row of small supporting cells called satellite cells. These satellite cells (perineuronal neuroglia cells) are recognized by the small dark staining nuclei surrounding each neuron. The cytoplasm of the satellite cells does not stain very clearly. Satellite cells can extend out along the axon, and it is often difficult to differentiate between satellite cells and the myelin Schwann cells surrounding the axons. Because sympathetic neurons are multipolar, the satellite cells which surround them form an incomplete ring interrupted periodically by the protrusion of the ganglion cells dendrites. Nerve fibers can be observed in between the neurons and glial cells.

 This slide contains the dorsal root ganglion from human spinal cord sections. At low magnification this ganglion is characterized by large spherical neurons which are grouped together with bundles of fibers between the groups. Sometimes the *neurons appear to be lined up in rows near the periphery of the ganglion*. Note that the neurons in this section of dorsal root ganglion vary in size (15 -120 μm) and are *nearly completely enveloped by a well-developed capsule of satellite cells*.

 The *centrally located nuclei* of spinal ganglion cells are pale staining with a prominent nucleolus. Connective tissue, which is found outside the satellite cells of the ganglion, is continuous with the connective tissue of peripheral nerves. It is usually not possible to distinguish the point where the cell body and the single process join.

Compare this slide with *Slide #37* (sympathetic ganglion) and use the following criteria to help you distinguish the two ganglion types:

a) Location of neurons within the ganglion

(evenly dispersed vs aggregated)

(b) Completeness of the satellite cell capsule;

(c) Location of nuclei within the cell body; and

(d) The type of neurons present (pseudounipolar vs multipolar).